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# ADVANCED FLIGHT DESIGN SYSTEMS

## SUBSYSTEM PERFORMANCE MODELS

JUNE 1980

CONTRACT NO. NAS9-15793

### EXECUTIVE SUMMARY

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**TRW**  
DEFENSE AND SPACE SYSTEMS GROUP



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## 1. INTRODUCTION

Subsystem performance analysis is required in Flight Design to assess the capability of the Environmental Control and Life Support System (ECLSS) to support the flight requirements and define operational procedures under contingency flight conditions. Current ECLSS modeling techniques are limited in the variety of configurations and they employ batch mode computer programs execution methods. Future spacecraft will require analysis of both a greater variety and a greater number of ECLSS than for previous spacecraft programs. Improvements in the variety of configurations that can be modeled and a reduction in effort required for modeling and analysis can be accomplished by developing a modular computer program which operates interactively.

An effort has been conducted to develop a modular interactive ECLSS performance analysis tool. The final reports on the effort are included in an Executive Summary and two Technical Reports. The Technical Reports include a User Guide and a sample model.

This Executive Summary presents an overview of the effort.

The Technical Reports include a User Guide which, due to the modular nature of the Program Library, includes a greater degree of technical detail than one for a conventional program. A sample model report supplements the User Guide and illustrates a complete ECLSS model set up and execution.

## 2. PROGRAM DESCRIPTION

Evaluation of various Environmental Control and Life Support Systems (ECLSS) performance may be conducted by the application of the subject interactive computer program with which the user accesses a library of routines simulating the performance of various components and functions common to ECLSS. These routines are assembled with a driver routine (MAIN) to simulate the particular ECLSS under consideration. The assembled program is then loaded and executed to produce the transient performance parameters of the ECLSS under prescribed boundary conditions.

The assembly procedures for a program are as follows. The master library of routines is extracted from a secure file. The user has the option to enter a MAIN routine (as for initial development of an ECLSS model), or extract a particular MAIN from his individual library (as for update/edit and/or additional studies with a previously developed ECLSS model). The extracted MAIN may be altered as part of the update/edit process. The program is then MAP'ed and the MAIN may be stored in the user's file for future use. The particular ECLSS program is then ready for execution.

The execution procedure includes a variety of input/output options, which are entered interactively through user prompted displays. The component characteristic data and initial conditions may be read in from restart data stored previously or entered directly. If the user desires, the system will output a schematic of the ECLSS modeled. The user has the option to select particular nodes (component locations) to be included in tabular output or the system will default to include output for all nodes defined in the model. If plots are desired, the user simply defines the particular parameters to be plotted. Restart data may be stored for future use. Up to this point the program is executed in an interactive mode. The program then transfers to a second stage of execution.

The second stage of execution is passive in the sense the data is processed with no interaction on the part of the user except to produce hard copy of the output. The processing accesses Electrical Power System (EPS) data and/or trajectory data for orbital heating automatically, if required. The data can be accessed from tape, secure files, or interface to other programs resident in the system. This stage of execution produces the tabular and plot data.

Two catagories of Routines make up the library. The first catagory is Referenced Routines, which are directly referenced in the user's MAIN. The second catagory includes the Unreferenced Routines which are automatically executed, but are not referenced directly by the user.

## 2.1 REFERENCED ROUTINES

The User Guide presents a description of the functions, application, and parameters associated with those Library Routines which are directly referenced in the user's MAIN. These include Program Control Routines, Component Performance Routines, and Input Utility Routines as summarized in Tables 2.1.1 through 2.1.3. The User Guide includes the reference procedure, interactive communication, and a cross reference to the various parameters for dynamic communication.

Table 2.1.1 Summary of Program Control Routines

START	Initialization control
PRINT	Boundary Condition Routine communication, timing control, and output control
LOOP	Timing control for first referenced ECLSS component in closed loop system
CONVRG	Convergence control in closed loop system

Table 2.1.2 Summary of ECLSS Component Performance Routines

PLATE	Forced cooled internal heat generating equipment
EVAP	Evaporator
SPLIT	Branching of coolant flow
MIX	Mixing of coolant legs into a single junction
MOD	Controlled proportioning of flow between two branches
RAD	Radiator panel
EXCH	Counterflow and parallel flow heat exchanger
HEATER	Controlled fluid line heater
ATMO	Atmospheric compartment (Cabin)
LIOH	Carbon Dioxide removal with Expendable Lithium Hydroxide
CONXG	Condensing Heat Exchanger, condensing side
CONXI	Condensing Heat Exchanger, interface (sink) side

**Table 2.1.3 Summary of Input Utility Routines**

TABLE	Linear interpolation of dependent variable in tabular data.
STEP	Interpolates tabular data as step function.

## 2.2 UNREFERENCED ROUTINES

User Guide presents a description of the functions and parameters of those library routines which are automatically brought into execution as a result of use of and/or specific option selection with respect to the referenced routines of Section 2.1. Only those library routines with which the user has interactive communication and/or may desire dynamic communication are included. These types of routines include Boundary Condition Routines and Output Routines as summarized on Tables 2.2.1 and 2.2.2.

Table 2.2.1 Summary of Boundary Condition Control Routines

COUPL	Provides for initial cross coupling of thermally connected nodes.
REPS	Provides data array for electrical power assignment.
CONSUM	Provides for integration of expended or generated media for various source assignments.
TRAJ	Performs incident (orbital) heating calculations.
SHAD	Assembles absorbed (orbital) heat for a panel.

Table 2.2.2 Summary of Output Routines

NODPRT	Displays fluid property data with generic names at selected print frequency.
NASPRT	Displays fluid property data with assigned node names at selected print frequency.
GASPR	Displays atmospheric property data at selected print frequency.
CONPRT	Displays consumables data for referenced sources at selected print frequency.
PLOOT	Stores data for plotting.
SCHEM	Displays modelled system schematic.

### 3. PROGRAM DEVELOPMENT

The library was developed to operate in an interactive mode on the NASA/JSC UNIVAC 1110 EXEC VIII computer system via the Hazeltine 4000 terminals. These terminals are available at various locations on the JSC site. Most of the interactive development and testing was conducted in the Mission Planning Laboratory (Bldg. 30).

The control routines and several of the component routines were developed first. This approach afforded early system testing parallel with the unit testing. As new Component Performance and Boundary Conditions were developed the testing was conducted by expanding or modifying the MAIN to execute the new routine. The final MAIN utilized all of the component routines and is capable of exercising all of the program options. This MAIN was also used as the sample model.

#### 4. CONCLUSIONS AND RECOMMENDATIONS

The program as designed and developed is applicable for performance analysis modeling of a variety of ECLSS. During development, consideration was given to the specific requirement of processing several models over an extended period of time such as for operational STS payloads. This consideration resulted in the following design characteristics.

- 1) A restart capability in which the user interactively modifies (updates) the component characteristics and exercises different options from a previous execution.
- 2) The production of a modeled system schematic to advise the user of the current configuration of the ECLSS model with which he is operating.
- 3) The print characteristic which identifies the type of component at each node either with an automatic generated generic name or a user assigned name.

The program was developed to minimize requirements for modification to the MAIN. This is accomplished by including a large variety of system configuration and output options in the interactive execution.

The program has a growth potential for applicability to future ECLSS. The modular nature affords the addition of new component routines as they are required. In addition, the consumables bookkeeping system is compatible with the more advanced closed system (regenerative) type of ECLSS components.

A relatively simple but effective shadowing technique, for general cases in which individual spacecraft components block the view of solar energy to other components, has been developed.

The parameters included in the restart data should be extended to include the tabular data (used in Routines Table and Step). This would greatly simplify the re-execution of models which use a large quantity of tabular data.